# REPORT DOCUMENTATION PAGE

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# Devices Based on Silicon Carbide Alloyed with Germanium

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August 2003

A progress report to the Office of Naval Research:
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Contract number: N0001-4-00-1-0834

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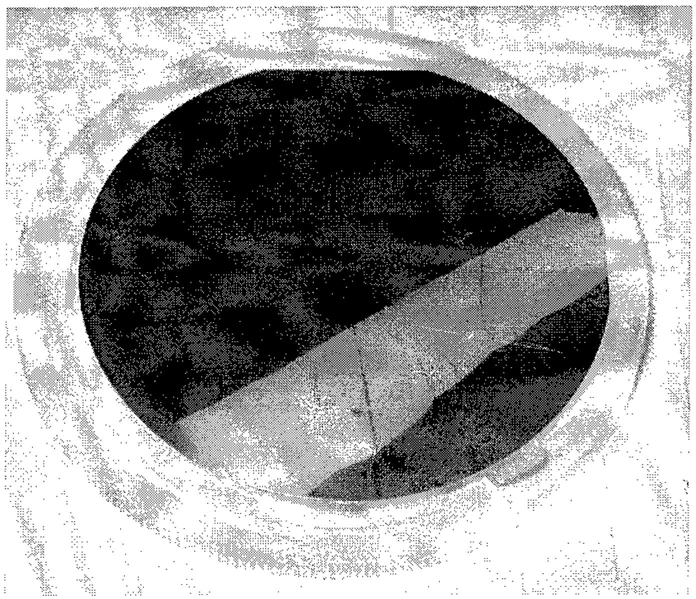
# Devices Based on Silicon Carbide Alloyed with Germanium

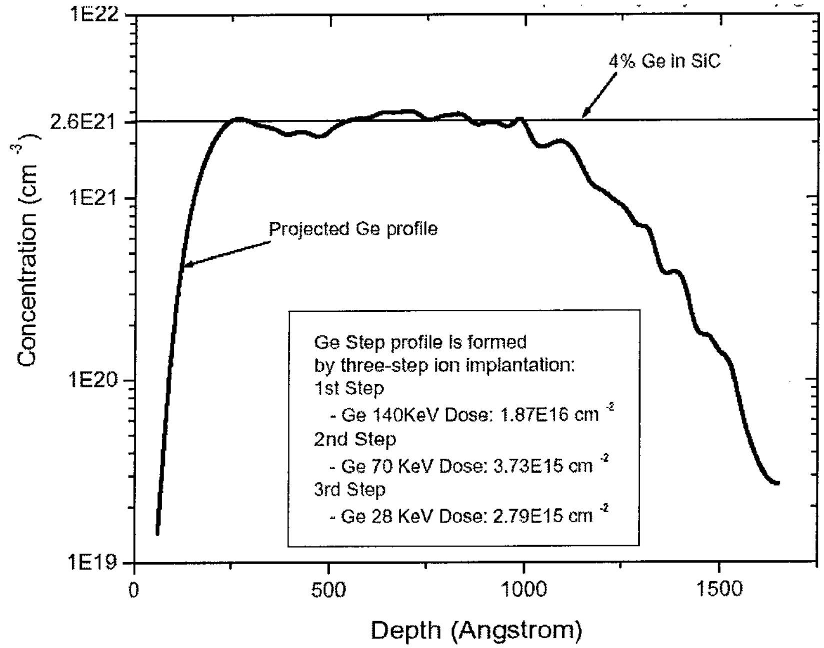
- James Kolodzey, University of Delaware
- Uniqueness: fabrication and characterization of new alloys of SiC and Ge
- Objective: investigate suitability of the alloys for SiC-based heterostructures.
- Progress & results: we produced the alloy and found the Ge is substitutional with no defects, is stable up to 1600 C, and has promising device proprieties
- References: J. Kolodzey et al., "Pseudomorphically Strained Layers in 4H-SiC formed by Germanium Implantation," MRS Fall Meeting 2002, Mat. Res. Soc. Symp. Proc. v. 742, 2002, pp. K6.7.1 - K6.7.6.

# Devices Based on Silicon Carbide Alloyed with Germanium

- What applications of Navy interest will this impact?
  - high speed, power, temperature SiC heterostructure devices and circuits for electric systems
- Do you anticipate transitions, and if so to what program?
  - If successful, this project will provide an impact similar to that of the nitride WBG materials system, but with a mature substrate

# Material Characterization of SiC:Ge (4% Ge), 2003

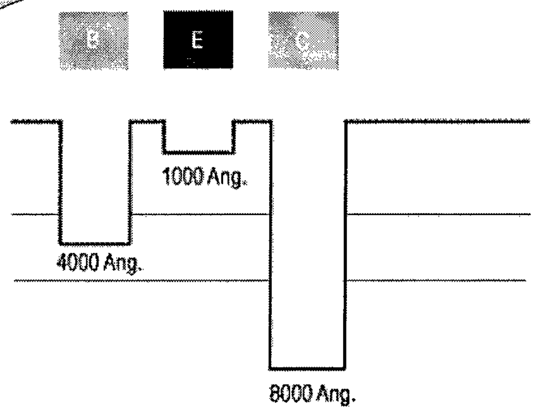




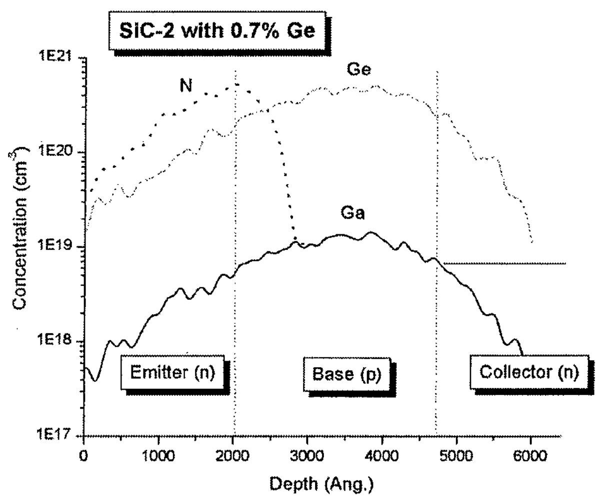

(left) SiC:Ge photo for the as-implanted wafer of 4H-SiC. The white stripe in the central area was masked from the implantation ions; while the dark area is where it received the Ge ion beams.

(right) Before the ion implantation, the Ge distribution was simulated using James Ziegler's SRIM software. The projected Ge ion distribution profile, as well as the ion implantation steps and doses for each step, is shown in this graph, for SiC sample NG4per03

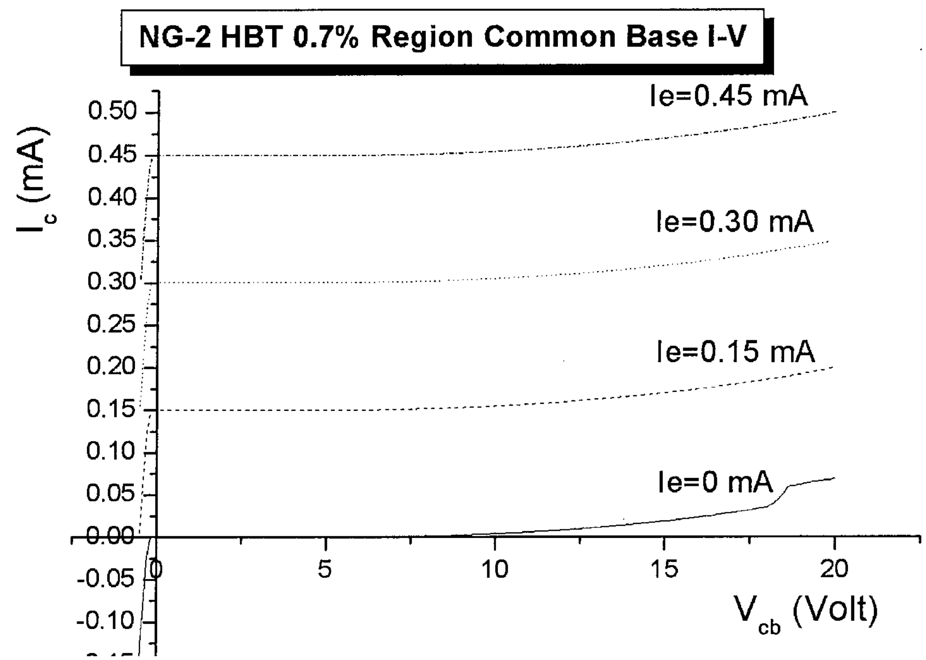
# Characteristics of npn bipolar transistor of 4H-SiC with 0.7 % Ge layer as the base region.




above: cross sectional etch profile of the transistor SiC-1

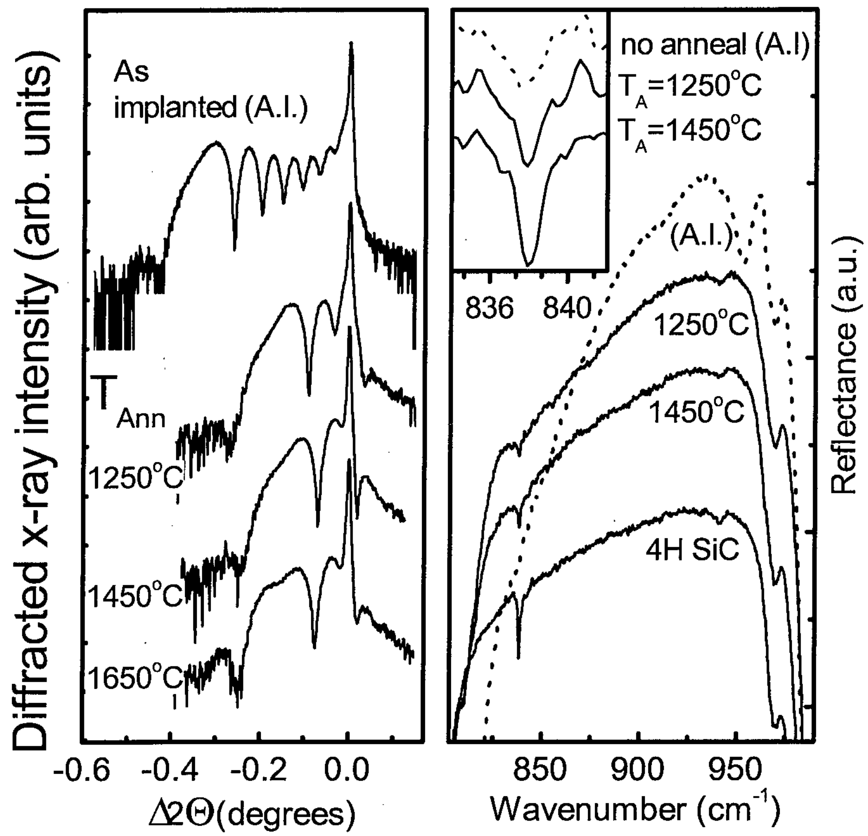



above: simulation result of the ion implantation, showing the npn emitter (N-doped) , base (Ge and Ga doped) and collector regions




above: The current voltage characteristics show a forward common base current gain $\alpha = 0.8$. This device is being optimized in this program.

# Thermal stability of the implanted SiC:Ge (~0.35% Ge) was investigated by HRXRD and FTIR reflection measurements




(left) x-ray spectra of SiC:Ge samples (Ge=0.3%) as-implanted (A.I.), and after 10 minute anneals at 1250°C, 1450°C and 1650°C.

(right) Infrared reflectance, where the incident light is 80° with respect to c-axis, for as-implanted sample (dotted line), and the SiC:Ge layers annealed at 1250°C and 1450°C. The 4H-SiC substrate reflectance is also shown.

After annealing, the new 945cm$^{-1}$ mode observed after implantation disappears and the characteristic 4H vibration reappears. The inset shows a close-up of the evolution of the 838cm$^{-1}$ 4H-FTO mode with annealing.